Effect of Physical Factors on Separation Efficiency of GAS From Oil Case Study in Alif Oil Field (Block 18)

Sleem Qadri Mohammed Saleh*

Abstract

Oil produced from oil well often has large amounts of dissolved natural gas, which has not been released from oil despite at lower pressure than saturation pressure. Therefore, it is necessary to separate these quantities of natural gas from oil and access to oil to the state of stability, taking advantage of natural gas separated from oil economically.The design of different types of technological separators depends on many factors affecting on the efficiency of their work. The most important of factors are the pressure, temperature and geometric dimensions of the separator.In this research, a large amount of field data (from the Alif field (block 18) were perused to investigate the effect of these factors on the efficiency of the separating process of the natural gas from oil. The number of separation stages that ensure the highest efficiency of natural gas was also identified. The optimum pressure for each stage of the separation process in the Alif field (block 18) was determined. The flash calculation was used to investigate the effect of pressure and temperature on separation efficiency of natural gas from oil flash calculation. The results show that an increasing in pressure when the temperature is constant increases the efficiency of separation process. For example, when the pressure separation is (90 psig) and the temperature is (155 ^{0}F), (n_L= 0.4595%), when the pressure increases to (250 psig) and the temperature (155 ^{0}F), the efficiency of separation process increases (n_L= 0.5256%).The effect of number of stages in the separation efficiency was also investigated. It was shown that increasing the number of stages to five stages increases productivity from (0.45%) to (0.99 %.) The effect of the diameter of the separator and retention time of oil inside in separator on efficiency of the process of separating the gas from oil was studied in this paper. The increase in diameter of separator from (12,75 in) to (30 in) increases the efficiency of the separation process by (33%), and the increase in the retention time of oil inside the separator from (1min) to (10 min) increases the efficiency of separation process by (90%).

keywords: Separation efficiency, Alif field (block 18), Physical parameters.

Introduction:

Crude oil may contain significant quantities of natural gas dissolved in it. So it was necessary to isolate such large quantities of natural gas and make use of them economically.

The process of separation of natural gas from oil make the oil safer during transport and storage. The distribution of hydrocarbons between oil and gas during the separation process is based on the assumption that the system of oil-gas is in case of equilibrium (when the pressure and temperature at any point in oil and gas is constant). The change in pressure and temperature in balanced system leads to imbalance of the equilibrium systems. The efficiency of the separation process depended on many factors such as the coefficient of equilibrium, pressure, temperature and chemical composition of the mixture of oil and gas.

There are many scientific studies about the effect of physical factors. Below is a brief review for the most important ones [2]:

- Wilson,(1968) proposed a simplified thermodynamic expression for estimating *K*-values. The expression generates reasonable values for the equilibrium ratio when applied at low pressures.

- Standing, (1979) derived a set of equations that fit the equilibrium ratio data of Katz and Hachmuth (1937) at pressures less than 1000 psia and temperatures below 200°F, which are basically appropriate for surface-separator conditions.

- Standing, (1981) proposed an empirical correlation for estimating the oil formation volume factor as a function of the gas solubility, Rs, the specific gravity of stock-tank oil, γo, the specific gravity of solution gas, γg, and the system temperature, The advantage of using Standing's correlation is that it gives the density of the oil at the temperature and pressure at which the gas solubility is measured, and therefore, no further corrections are needed, that is $\Delta\rho_P$ and $\Delta\rho_T$.

This study investigates the effect of physical factors (pressure, temperature) on the efficiency of separation of the natural gas from crude oil, and it also investigates the influence of other factors such as the dimension of the separator, the retention time of the gas within the separator and the steps of separation processing in Alef field.

The general objective of this research is to study the effect of different factors on the efficiency of separation gas from oil and design the optimum

* College of Petroleum and Minerols – Shabwa University of Aden. Received on 25/6/2018 and Accepted for Publication on17/6/2020

conditions for system of processing of fluids products which reduce the losses of light hydrocarbons to minimum values.

Material and methodology:

The effect of physical factors on the efficiency of the separation process of laboratory sample of crude oil from Alif field (block 18) was calculated. Table 1, showed the chemical composition of sample from Alif field at 670 psig and 125°F with mole fraction Z_j for each component and this was the most important data in our research [5]. It has been found that the non-hydrocarbon components have small a mole fraction of CO_2 with no presence for N_2 and H_2S, so the sample contains sweet gases. It has also been found that the most available component was methane representing 43% of sample composition and comes next the mole fraction of C_{7+} equaling 40%. The sum of all component equal the unity 100 % . So expected that there was a lot of dissolved gas in this sample of oil. The critical pressure was (P_{cj}), critical temperature (T_{cj}) and boiling point temperature was (T_{bj}) for each component of sample as shown in Table1 [6].

Table 1: Mole fractions and chemical composition with physical properties of sample from Alif field (block 18)

Comp.	Z_j	P_{cj} (psig)	T_{cj} (°R)	T_{bj} (°R)
CO_2	0.002	1071	547.91	350.74
N_2	0	493.1	227.49	139.55
C_1	0.432	666.4	343.33	201.27
C_2	0.0495	706.5	549.92	332.51
C_3	0.0468	616	666.06	416.25
Iso -C_4	0.0088	527.9	734.46	470.78
n-C_4	0.0213	550.6	765.62	491.08
Iso -C_5	0.007	490.4	829.1	542.12
n-C_5	0.0084	488.6	845.8	556.92
C_6	0.0143	436.9	913.6	615.72
C_7+	0.4099	268.55	1209.09	741.04
SUM	1			

The research was conducted as follows:

1- The effect of Temperature and Pressure on the Separation Process:

Flash calculation was employed to calculate the effect of physical factors on separation efficiency of natural gas from oil. It gives the proportion of each component of oil in the case of liquid and in the case of the gas at the certain pressure and temperature. The Standing Correlation was used [2], which has lowest absolute average error.

The computational procedures summarized in the following steps:

1- Assumed several values of pressure like (30 , 90 ,….ect) psig , and several values of temperature like (116 , 150 ,155,….ect) °F, tried to put this assumed values as near as much to the conditions of pressure and temperature in Alef field.

2 - Calculated equilibrium constant (K_j) , mole fraction of gas phase component, (Y_j) % and mole fraction of liquid phase component (X_j) %, at those conditions for all assumptions by using Standing Correlation.

$$Kj = \left(\frac{1}{P+14.7}\right) * 10^{(Fj)} \qquad ....(1)$$

Where:

Kj - equilibrium constant.

P -pressure, psig.

Fj - constant.

$$\Sigma X_j = \frac{Zj}{1+ng*(Kj-1)} = 1 \qquad ....(2)$$

Where:
X_j- mole fraction of each liquid component, %.
Zj - mole fraction of components coming from upstream, %.
ng - mole fraction of gas, % .
K_j - equilibrium constant = Y_j/X_j .
$Y_j = X_j * K_j$ ....(3)
3- Calculate the composition of fluid at various assumption values of pressure and tempreture.
$nl = 1 - ng$ ....(4)
Where:
nl - the mole fraction of liquid in feed, %.
ng -the mole fraction of gas in feed %,

2- Selecting the Number of Stage and Optimum Pressure for each Stage:

Determine the number of stages of separation of natural gas from crude oil depends on pressure. The ratio of pressure was determined mathematically by taking the n root of the relativity between flow line and final pressure where n refers the chosen number of stage[3].

$Rap = (\frac{P1}{Ps})^{\frac{1}{Nst}}$……………………………….……(5)

Where:
Rap - pressure ratio.
Nest - number of stage.
P1- first-stage or high pressure separator, psig.
Ps - stock-tank pressure, psig.
Pressure at intermediate stage can then be designed with the following formula:

$Pi = \frac{p_{i-1}}{R_{ap}}$…………………………………...…..(6)

Where:
Pi - pressure at stage I, psig.

3- The effect of Pressure and Dimensions on the Gas Production Rate:

To study the Effect of the pressure and dimensions on the gas production rate, the following steps should be followed [3]:
1. Assume various range of pressure like (30,60,90,120,270,290 ….etc.).Values of pressure near to the Aleph field condition were chosen.
2 .Calculate the Z factor of gas and the viscosity of gas and the density of oil and gas at each pressure and temperature. (given from PVT calculation) [3]:. Example for the results of the calculation of previous coefficients at 90psig and 150^0F were equal: ρ_o=49.12,Ib ⁄ ft^3 ρ_g = 0.455 ,Ib ⁄ ft^3 , μ = 0.009 cp. and the Z factor = 0.978.
3. Calculate the drag coefficient (Cd) and this depends completely on Reynolds number by using the excel program.
4. Calculate the gas flow rate Q_g from the following equations:

$Q_g = \frac{D*104.7*(p_o-p_g)*100)0.5}{420*Z*T*(p_g*Cd)\ ^{0.5}}$, MMSCFD……...(7)

Where:
Q_g-gas flow rate in, MMSCFD.
D - diameter of separator in, ft.
ρ_o- density of oil in ,Ib/ft^3.
ρ_g- density of gas in, ,Ib//ft^3.
Z -deviation factor of gas.
T - temperature of system in, °R.
C_d- drag coefficient of system.
Repeat the same calculation at each diameter and length and each assumed pressure.

4- Effect of Retention Time and Diameter on the Cumulative Production of Oil :

The effect of diameter and retention time was studied as in the following steps [3]:
1- Assume various ranges of retention times like (1minute, 2 minutes…etc.). These values were selected near to the field's retention time and it is suitable for the field's production rate of oil.
2- Dimensions of separation from API design were selected.
3- Calculate the oil flow rate from the following equations.

$Q_o = \frac{(3/4)\times(D^2)\times L_{ss}}{1.42} = \frac{bbl}{day}$…………………..(8)

Where:
D – diameter of separator, ft.
L_{ss}- length of separator, ft.
4- Calculate the cumulative oil at 1 year.
5- Repeat the previous calculation for various assumed values of diameters and seam to seam length and assumed range of retention time.

Results and Discussion:

The results of the study of the effect of physical factors on the efficiency of the process of separating gas from oil were created as follows:

1- Effict of temperature and pressure on separation proceces:

The effect of pressure and temperature on efficiency of the separation process of a laboratory sample of crude oil collected from Alif field (block 18) was investigated.
For explicitly the flash calculations for C_1 at the 30 psig and 155 °F and the rule will applied on all components at all assumed values of temperature and pressure as the following:

$Kj = \left(\frac{1}{30+14.7}\right) * 10^{(3.6)} = 88.4$

Using the spread sheet by excel program and by using the trial and error method, it was found that the number of mole of gas ng = 0.59 %.

and the mole fraction of liquid phase in each component is:

$$X_j = \frac{0.432}{1+0.59*(88.4-1)} = 0.0083\ \%.$$

Y_j = 0.0082 * 88.3 = 0.73 %.

nl = 1 - 0.59 = 0.41 %

By repeating the previous calculations of C_1 for (C_2 to C_7), the final results of effect of pressure and temperature on efficiency of separation process of natural gas from oil are shown in Table 2 and Figure 1.

Table 2: Mole of liquid for various temperatures and pressures.

T, ^{0}F	116	130	140	150	155	160	175
P, psig	Mole of liquid, %						
30	0.436	0.428	0.422	0.415	0.412	0.408	0.397
90	0.461	0.456	0.452	0.449	0.447	0.445	0.438
150	0.468	0.464	0.462	0.459	0.458	0.456	0.452
210	0.469	0.467	0.465	0.464	0.463	0.461	0.458
270	0.469	0.468	0.466	0.465	0.464	0.464	0.461
330	0.468	0.467	0.467	0.465	0.465	0.464	0.462
390	0.466	0.466	0.466	0.465	0.464	0.464	0.462
450	0.464	0.464	0.464	0.464	0.463	0.462	0.462

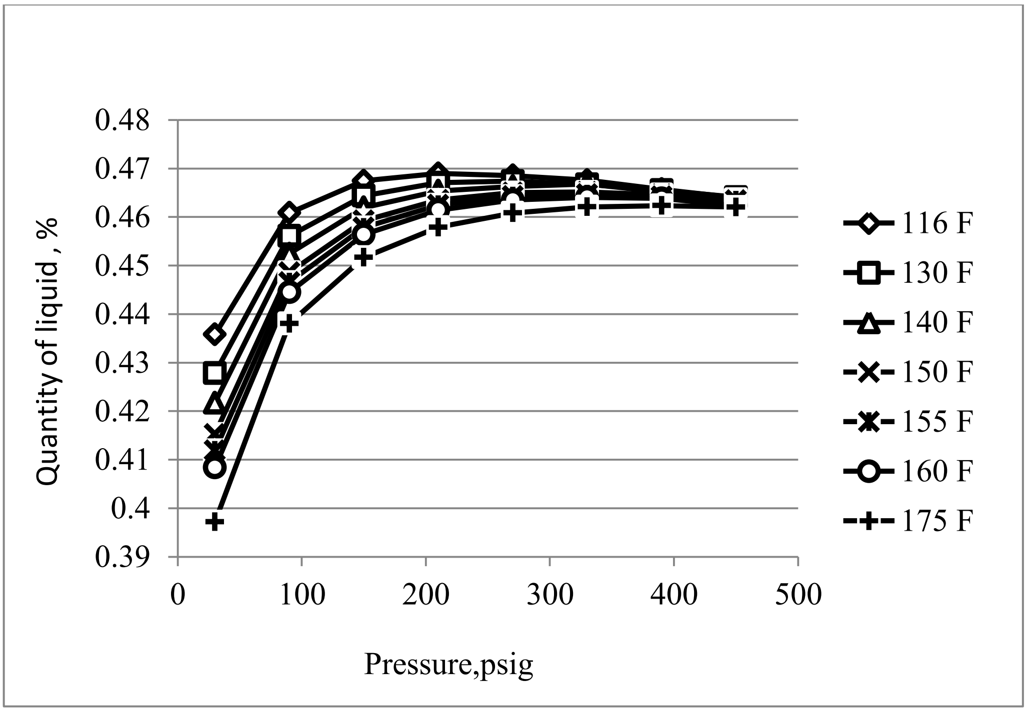

Figure 1: Quantity of liquid versus temperature and pressure

Figure 1. shows the effect of temperature and pressure on the separation process as follows:

1- At a constant temperature and as pressure increases, the efficiency of separation process increases. This is due to the fact that when pressure increases, the gas will have lower velocity in separator, then it will remain longer time in separator, and the small droplets of the liquid in the vapor phase will take its time to drop in gravity settling section due to gravity effect. It was also noted that increasing separator pressure from 30 psig (nl = 0.4358%) to the 270 psig (nl = 0.4686%) , causes a large increase of efficiency of separation process. At pressure above 270 psig, there will be a small increase due to the phenomena of gas blow by, and the liquid carryover. Then from 330 to 450 psig(nl ≈ 0.4657%), there will be approximately unnoticed or no increase in the efficiency of the separation process.

2- At constant pressure: The efficiency of the separation process will increase as the temperature of the fluid stream decrease by 4.4 %, because the temperature increase will vaporize the light hydrocarbon and then increase the losses during the separation process bad separation process.

3- **Selecting the number of stage and optimum pressure for each stage:**

It is clear that for each facility there is an optimum number of stages. In most cases the optimum number of stage is very difficult to determine as it may be different from well to well and it may change as the well flowing pressure declines with time. Table 3 is an approximate guide to the number of stage in the separation, excluding the stock tank, which is somewhat near optimum as indicated by field experience. Table 3 is meant as guide and should not replace the flash calculation, engineering studies, and engineering judgment [4].

Table 3: Stage separation guideline

Initial separator pressure, psig	Number of stage
25-125	2
125-300	2-3
300-500	3
500-700	3-4

Ratio of pressure is a factor used in determining the stages pressure by dividing it on previous stages pressure value. The number of stages that separation processing need to determine the pressure ratio might be selected . It is easy to select stages of separation from Table 3 for pressure is below than 500 psig, but it is difficult to select the number of stages of separation for pressures higher than 500 psig.

According to equations 6 and Table 3, the pressure and temperature ratio is counted as follows:

$Rap = (\frac{684.7}{14.7})^{\frac{1}{5}} = 2.15$

$RaT = (\frac{125}{60})^{\frac{1}{5}} = 1,07$

Then to know the pressure and temperature of the following stages, we divided the initial pressure and temperature by the pressure and temperature ratios as following:

$Rap = \frac{684.7}{2.15} = 317.6$ psig. This is the pressure of stage 2.

$RaT = \frac{125}{1,07} = 116,8\ ^0F$. This is the temperature of stage 2.

After that, the previous steps were repeated for the pressure and temperature then the results were summarized in Table 4.

Table 4: Stage's pressure and temperature

Stage	Pressure, psig	Temperature, ^0F
1	684.7	125
2	317,6	116,8
3	147,3	109,08
4	68,33	102
5	31,7	95
6	14,7	90

Table 5: Relationship of the separation stages with pressure, temperature and mole of liquid.

T, ^{0}F	95	150									60
N^0	Stg.1	Stg.2			Stg.3			Stg.4		Stg.5	St. tank
P, psi	670	550	290	270	150	120	90	75	60	30	25	14.7
nl,%	0.33	0.46	0.47	0.46	0.89	0.90	0.90	0.97	0.97	0.96	0.99	0.99

As it is shown from Table 5, the effect of the number of stages of separation on the efficiency of process can be explained as follows :

The number of stages of separation depends on the pressure of the production wells that enters the first stage of separation. The increasing in the number of stages of separation leads to an increase in the efficiency of the work of separators, this is due to the indirect reduction of pressure. For the conditions of separating gas from oil in Alif field, it was found that the number of appropriate separation stages is five stages.

3- Effect of the pressure and diameters on the gas production rate:

The amount of gas resulting from the separation process is related to the dimensions of separator and pressure inside it, in addition to other factors, the most important of which are the composition and properties of gas and coefficient of friction. Increasing the diameter of the separator increases the pressure and as a result increases the speed of the crude oil inside the separator. This leads to an increase in the impact of gravity and increases the amount of gas separated from oil. The results are summarized in Table 6 and Figure 2.

Table 6: The effect of separator diameter and the pressure on the efficiency of the separation process at Lss = 5 ft

P, psig	30	60	90	150	210	270	290	330	390	450
D, in	productivity of gas ,(MMSCFPD)									
12.75	0.94	1.14	1.44	2.03	2.62	3.00	3.15	3.43	3.82	4.02
16	1.09	1.33	1.68	2.37	3.06	3.51	3.68	4.00	4.47	4.70
20	1.24	1.51	1.91	2.68	3.47	3.99	4.18	4.54	5.08	5.32
24	1.34	1.64	2.06	2.91	3.75	4.30	4.52	4.91	5.48	5.76
30	1.40	1.70	2.15	3.03	3.91	4.48	4.70	5.12	5.71	6.00

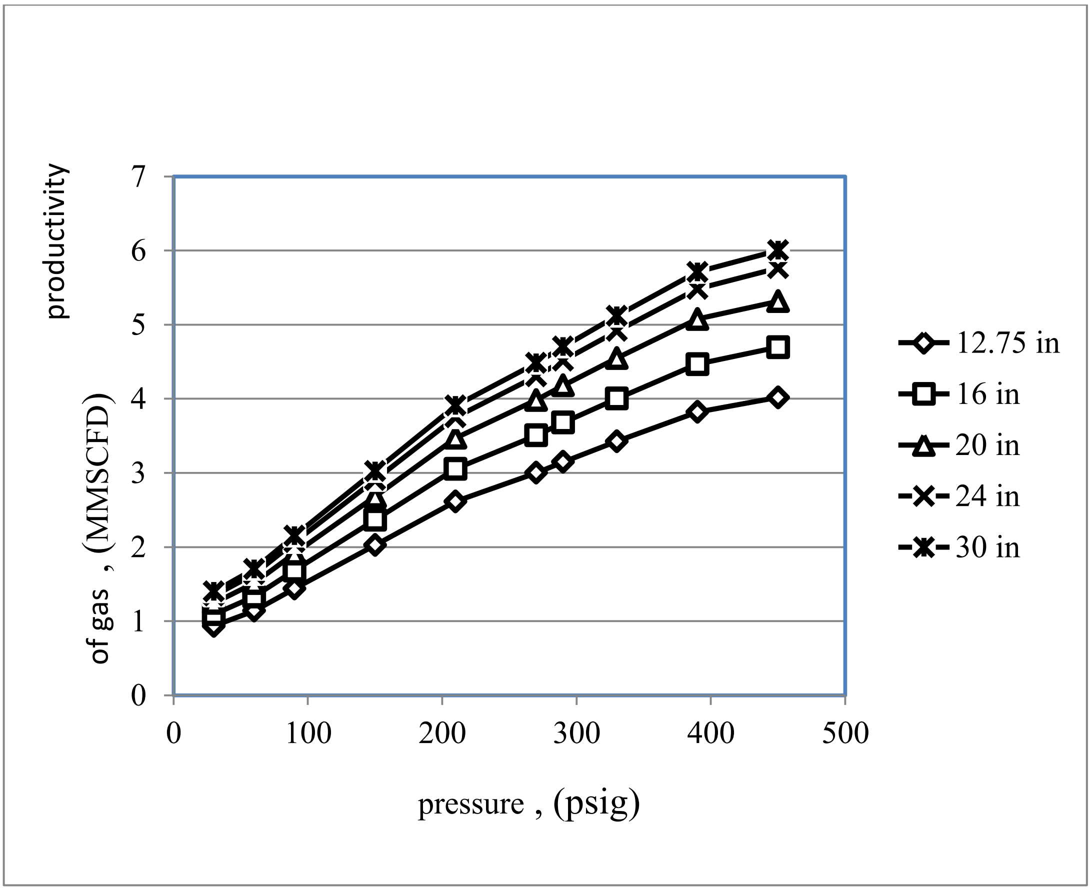

Figure 2: Pressure versus. diameter and productivity of gas at L_{ss} = 5 ft

As shown in Table 6, **a**n increase in the diameters of the separator when the pressure is constant, increases the efficiency of the gas separation process. When the pressure increased, while the diameter of separator is constant, the efficiency of separation process increases. This is due to the positive relationship between the diameter of separator and its work. Increasing the diameters of the separator at D = 12.75 in. to D = 30 in, when P = 30 psig, increases productivity of gas from Q_g= 0.936 MMSCFPD, to Q_g= 1.339 MMSCFPD.

In general, it was found that increasing diameter of separator from 12,75 in to 30 and increasing the pressure of work of separator from 30 psig to 450 psig, increased the efficiency of gas separation from oil by 33%.

4- **Effect of retention time on the cumulative production of oil**:

The efficiency separation of gas from oil is determined by an increase in the amount of gas (from the upper unit in separator) or a decrease in the amount of liquid (from the liquid collection and drainage unit bellow the separator). Increasing the retention time of crude oil inside the separator increases the efficiency of the separation process (decrease in the amount of liquid resulting from the separation process) due to the increase gravity effect [7].

Example for effect of retention time on the cumulative production of oil at 1minute the oil flow rate at 1 minute, D = 12.75 ft. and L_{ss}= 5ft.

$$Q_o = \frac{(3/4)\times(D^2)\times L_{ss}}{1.42} = 429.3024 \,, \frac{bbl}{day}$$

4- Calculate the cumulative oil at 1 year**.**

$$Q_o = \frac{(3/4)\times(D^2)\times L_{ss}}{1.42} = 429.3024 \times 365 \text{ day} = 156695.37, \text{ bbl}$$

The result presented in Table 7 and Figure 3.

Table 7: Retention times with productivity of liquid with diameters at L_{ss}= 5 ft

Time, min	1	2	3	4	5	6	7	8	9	10
D, in	productivity of liquid *1000, bbl									
12.75	156.7	78.4	52.2	39.2	31.3	26.1	22.4	19.6	17.4	15.7
16	246.8	123.4	82.3	61.7	49.4	41.1	35.3	30.9	27.5	24.7
20	385.6	192.8	128.5	96.4	77.1	64.3	55.1	48.2	42.8	38.6
24	555.2	277.6	185.1	138.8	111.0	92.5	79.3	69.4	61.7	55.5
30	867.5	433.8	289.2	216.9	173.5	144.6	123.9	108.4	96.4	86.8

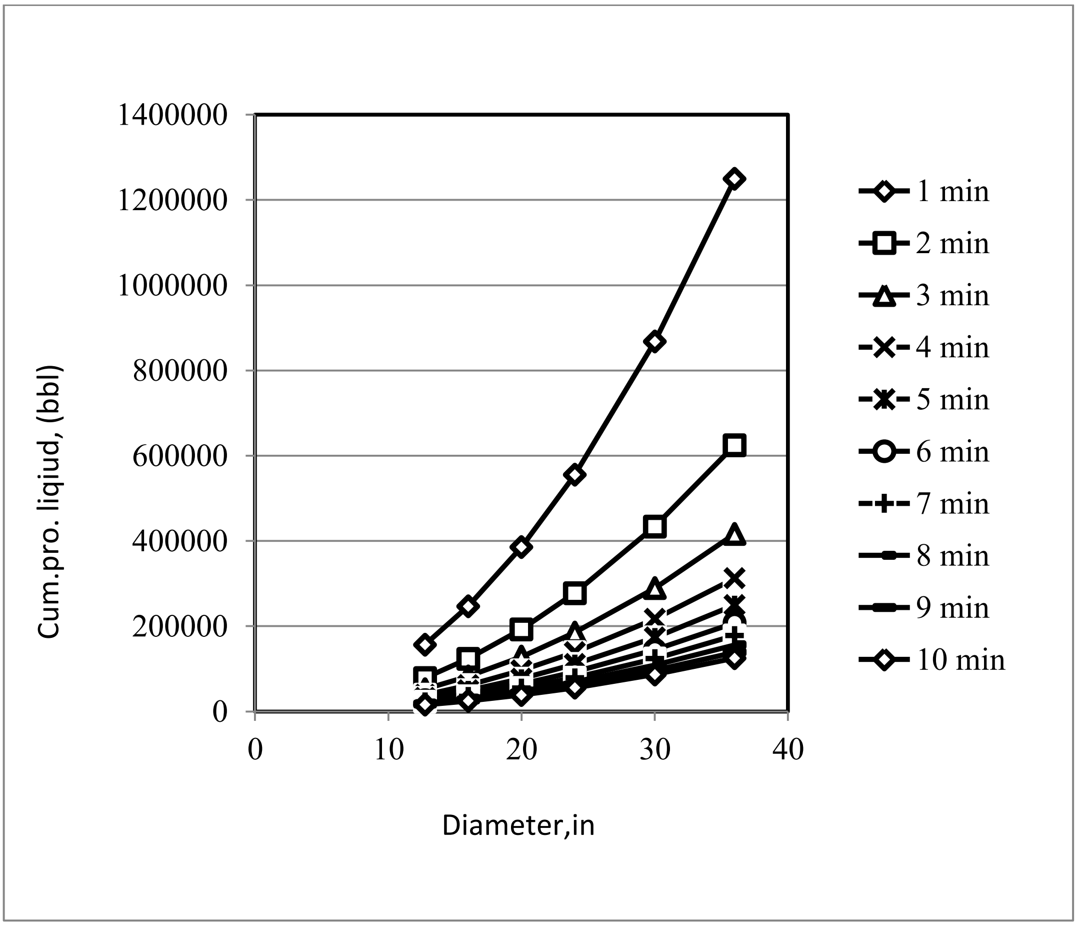

Figure 3: Cumulative produced liquid vs. diameter at different values of retentions time at L_{ss}= 5 ft

From Table 7 and Figure 3, we notice that the increase in the separation time (retention time) leads to an increase in separation efficiency (decrease in the quantity of liquid produced).

To lengthen the retention time at constant diameter increases the cumulative liquid production in year decrease, at 30 in with retention time = 1 min, Q_L= 867517.61 bbl, and at 30 in with retention time =10 min, Q_L= 86751.76 bbl.

5. Conclusions

The following conclusions can be drawn from the obtained results:

1- Pressure and temperature directly affect the separation efficiency of gas from oil. The efficiency of separation process is directly proportional with number of moles of liquid, at a constant temperature, it is going to be slightly inverse proportional, and at constant pressure, the temperature is inversely proportional with number of mole of liquid. Increasing pressure when the temperature is constant increases the efficiency of the separation process by 10.2%. Increasing the temperature when pressure is constant decreases the efficiency of the separation process by 4.4%.

2 - The number of stages of separation depends on the pressure of the production wells that enters the first stage of separation. Increasing the number of stages of separation leads to an increase in the efficiency of the work of separators, this is due to the indirect reduction of pressure. The number of stages that give the best efficiency for the Alif field (block 18) is five stages.

3- Selection of the appropriate dimensions of separators during the designing process depends on the working pressure and diameter of separator. The efficiency of gas separation from oil when the pressure is constant increases by increasing the diameter of separator from 12,75 in to 30 in by 33%.

4- Increasing the time of oil retention inside the separator from 1min to 10 min at different diameters leads to a reduction in the amount of liquid product from 867517.6,bbl. to 86751.8 bbl. This increases the efficiency of separation by 90 %.

6.Nomenclature.

y_i	Mole fraction of component I in the mixture	%
x_i	Mole fraction of component iin the mixture	%
P_{ci}	Critical pressure	Psia
T_{ci}	Critical temperature of the ith component	°R
$(T_c)_{c_{7+}}$	Critical tempreture of c_{7+}	°R
$(P_c)_{c_{7+}}$	Critical pressure of c_{7+}	Psia
Rap	Pressure ratio	Psia
Nst	Number of stage -1	N^0

References:

1- Ahmed, T.(1989).hydrocarbon Phase behavior (vol.8).Gulf Professional Publishing. P.78-140.
2- Ahmed, T. (2007). Equations of state and PVT analysis. Applications for Improved Reservoir Modeling. Gulf Publishing Company Houston, Texas.P.141-239
3- Arnold, K., & Stewart, M. (1999). Surface Production Operations, Volume 2: Design of Gas-Handling Systems and Facilities. Elsevier. P.35-174
4- Devold, H. (2013). Oil and gas production handbook: an introduction to oil and gas production. Lulu. Com.
5- Flopetrol johnston (AGUST 1984).P.V.T. stady report. Yemen Hunt oil company.SEPCO-P.V.T./S002
6- GSPA Engineers data book,10th ed. 1987. Tulsa, OK.
7- Hafezof A. & other. (2003) Collection, processing and storage of oil. technology and equipment. . P.201-208.

تأثير المعاملات الفيزيائية في كفاية عملية فصل الغاز الطبيعي من النفط، دراسة تطبيقية على حقل ألف (بلوك 18)

سليم قادري محمد صالح

الملخص

غالبا ما يحتوي النفط المنتج على كميات عالية من الغاز الطبيعي المذاب فيه والذي لا يتحرر من النفط حتى بعد انخفاض الضغط أقل من ضغط التشبع. لذاك كان لابد من عزل كميات الغاز هذه من النفط والوصول بالنفط إلى حالة الاستقرار، مستفيدين من الكميات الكبيرة للغاز الطبيعي المعزول اقتصاديا. تصميم الأنواع المختلفة للعوازل التكنولوجية تتوقف بالأساس على معاملات عديدة تؤثر في كفاية عملها، أهم تلك العوامل الضغط ، درجة الحرارة ، أبعاد العازل وغيرها من العوامل. في هذا البحث درسنا تأثير المعاملات السابقة في كفاية عملية فصل الغاز الطبيعي من النفط بوساطة بيانات حقلية من حقل ألف (بلوك 18). ، كما حددنا عدد مراحل الفصل التي تضمن أعلى كفاية لعملية فصل الغاز الطبيعي من النفط. أيضا تم تحديد الضغط الأمثل لكل مرحلة من مراحل الفصل. استخدمنا حسابات الفصل (Flash calculation) من أجل توضيح تأثير الضغط و درجة الحرارة في كفاية عملية فصل الغاز الطبيعي من النفط. بينت النتائج أن الزيادة في ضغط عمل العازل عند ثبوت درجة الحرارة يزيد من كفاية عملية الفصل. فمثلا عند ضغط العازل (90 psi) ودرجة الحرارة ($155\ ^0F$)، فأن ($n_L= 0.4595\%$). الزيادة في ضغط عملية الفصل إلى (290 psi) عند درجة الحرارة نفسها زاد من كفاية عملية الفصل ($n_L= 0.5256\%$). تبين أيضا أن زيادة درجة الحرارة أدت إلى خفض كفاية عملية الفصل بنسبة 4.4%. وضحنا أن عدد مراحل الفصل المثالية لحقل ألف (بلوك 18) هي خمس مراحل فصل، حيث زادت كفاية عملية الفصل من 0.465% إلى 0.99%. درسنا في هذا البحث تأثير قطر العازل و زمن بقاء النفط داخل العازل على كفاية عملية فصل الغاز من النفط. تبين أن الزيادة في قطر العازل من (12.75 in) الى (30 in) يزيد كفاية عملية الفصل بنسبة 33%. الزيادة في زمن بقاء النفط في العازل من (1min) إلى (10 min) زاد من كفاية عملية الفصل بنسبة 99%.

كلمات مفتاحية : كفاءة عملية الفصل، حقل ألف (بلوك 18)، المعاملات الفيزيائية.